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The state of the application of ecosystems services in Australia

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ABSTRACT

We review the environmental challenges, cultures and institutions in Australia that have allowed the concept of ecosystem services to be tested and adapted. In some instance the nation has embraced the opportunities offered with ecosystem services forming the core of several large-scale reforms and collaborations that have considered dependence of humans on ecosystems. In other ways, however, the opportunities have been overlooked as Australia lacks effective institutions to consider human–environment interactions holistically and strategically. The term "ecosystem services" appears widely but it is mostly used superficially: often with reference to only a few services. The full suite of services, benefits and beneficiaries if humans and the natural environment are to coexist in the long-term have not been systematically included in decision making and management. Insights are distilled that may be useful in the application of ecosystem services in other parts of the world. Stable and well-funded regional natural resource and river basin management institutions have vital roles. Governance reforms at the national and state (provincial scales) are also needed to apply ecosystem service frameworks and improve accountability for implementation of policy agreements.

1. Introduction

1.1. Opportunities for Australia

The concept of ecosystem services was developed by ecologists and economists to clarify and communicate the importance of the environment in people's lives and nations' economies. It enables the benefits that flow to humans from well-functioning ecological systems to be included in decision making on an equal footing with more tangible costs and benefits (Costanza et al., 1997; Daily, 1997). Ecosystem services were intended to integrate aspects of ecology and economics and build on, rather than replace, concepts like sustainable development that have been foci for government policy for several decades.

The key idea of the ecosystem services approach is that explicitly and systemically identifying the benefits and beneficiaries of ecological processes which will improve integration of social, economic and environmental considerations in strategic decision-making. Such frameworks offer powerful ways to address environmental, social policy and management challenges at scales ranging from local to national. This strategic thinking is vitally needed in relation to major policy challenges in Australia, including climate change, water allocation, population, and food security (Cork, 2010a).

In this commissioned paper we seek to take stock of the use of the ecosystem services in Australia to draw lessons of use domestically and internationally and to identify further opportunities to beneficially apply the concept. We consider how the unique combinations of culture and environmental challenges in Australia have allowed scientists, communities and policy makers to test and adapt the concept of ecosystem services and we distil some of the insights that might be useful to theoreticians and practitioners in other parts of the world.

1.2. Terminology

There is a debate about how to define ecosystem services and how to distinguish services from the ecological processes that lead to their generation, and the benefits that flow from them (Binning et al., 2001; Boyd and Banzhaf, 2007; Fisher et al., 2008, 2009; Maynard et al., 2010). We take the view that ecosystem services result when the components of ecosystems transform resources into a form that humans are able to turn into benefits, a definition that is consistent with both everyday usage and usage in the discipline of economics (Binning et al., 2001), but we recognise that slightly different interpretations are used by different studies cited in this paper.

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1.3. The evolving challenge of sustainable ecosystem management in Australia

Australia has a long history grappling with how to balance use of natural resources with conservation of the environment. Australia is one of the world's "megadiverse" countries (it is home to a very wide range of species found nowhere else). Australia has developed one of the world's most successful economies and a society blessed with strong educational, research and social-support institutions. The economy is largely based on clever (or fortuitous) use of natural resources, especially in agriculture and mining.

Australia has been occupied by humans for at least 40,000 years. By the time of colonisation by Europeans, the numerous Indigenous nations in Australia had developed sophisticated understanding of ecosystem processes and human dependence on them. Adaptation to the ecosystems involved nomadic lifestyles in some places and active management of ecosystems, notably with the use of fire, in many parts of the continent (Rose, 1996).

European occupation from 1788 resulted in widespread environmental changes. Early settlers brought an understanding of the natural world based on the United Kingdom and Europe, where soils are generally of higher fertility, rainfall is greater and more reliable, and the growth forms and strategies of vegetation are very different. The need to quickly establish the means to survive and prosper, led the settlers to focus on producing foods by growing crops and raising stock imported from Europe, and to establish export industries based on these commodities. This emphasised the use of provisioning ecosystem services at the expense of other benefits (Lines, 1991).

Extensive conversion of ecosystems since European settlement has been primarily in the southern half of the continent. Here, temperate forests, woodlands and grasslands were converted to pastures planted with European crops and fodder and grazed by stock animals with very different feet and foraging behaviours to native herbivores. This set in train processes that have led to salinisation and other degradation of large areas of land, soil compaction and erosion, and depletion of soil fertility. Overgrazing of rangelands and overexploitation of fisheries has also reduced the capacity of southern Australian ecosystems to generate services (State of the Environment Committee, 2011).

Throughout much of the 19th and 20th centuries, it was regarded as a responsibility of land owners to exploit potentially arable land by removing unproductive vegetation to allow grazing by stock and planting of crops (Tovey, 2008). Foresters were among the first to draw attention to the disappearance of forests as clearing of land escalated (Cork, 1997). Debate about how to balance land conversion with conservation escalated in the late 1970s as scientific evidence highlighted the decline in components of biodiversity. As this debate developed a central question was "what is the importance of biodiversity?" Initially, the focus for answering this question was on moral and ethical responsibilities for other species, but increasingly there was dialogue about the role of ecosystems in supporting and fulfilling human life.

As the concept of ecosystem services became popular in the USA and Europe in the late 1990s many Australian scientists, policy makers and environment-focussed interest groups were ready to consider how it might contribute to more productive dialogue. But for some, this concept was treated with suspicion; as another in a long string of popular concepts that might undermine progress in scientific disciplines such as ecology and economics. The past decade has seen ongoing consideration of the merits of ecosystem services approaches and attempts to adapt and modify the concept (Cork et al., 2007).

2. Responses to the sustainability challenges

2.1. Early responses by governments

Australians expect their governments to take more responsibility for environmental, social and economic management than in some other countries, such as the USA, where non-government and philanthropic organisations have played leading roles (Davis, 1971). While Australia also has active non-government organisations, the history of natural resource management in Australia is extensively influenced by government initiatives (as evidenced by the paradigms discussed below).

Many environmental, social and economic drivers have interacted to contribute to the ecosystem decline described above. Response to these complex drivers has often involved a short-term focus on only part of the problem, which has often reduced the resilience and adaptability of both the ecological and social systems (Walker and Salt, 2006; Walker et al., 2009). At the same time, however, there has been a succession of innovative institutional developments that have sought to recognise and manage multiple social and economic values of ecosystems, as indicated in the following examples.

Although built on the dispossession of Indigenous Australians, the practice of granting pastoral leases of land rather than freehold title to graziers in the more remote parts of Australia (in New South Wales, the Northern Territory, Queensland, South Australia and Western Australia; see Fig. 1) retained government ownership of the underlying land and other resources. In part this recognised the need to enable other parts of society access to different ecosystem services and maintain options for different uses in the future (Holmes and Knight, 1994; Productivity Commission, 2002). This has enabled a diverse range of overlapping uses, including ongoing access by Indigenous Australians to their customary lands for traditional purposes and timber production.

The need for clean and reliable water supplies for growing cities led to the reservation of many water catchments (for example, in the highlands behind Melbourne from 1886), which also conserved biodiversity and other values (Dudley et al., 2010). The extensive conversion of highly productive forests to agricultural land led to the establishment of state forestry agencies with explicit mandates to reserve forests and manage them to enable generation of multiple benefits, including: water, pasture, game, timber and other non-timber forest products. One example is the Victorian state forest agencies that were established from 1908 (Carron, 1985). In many instances, however, the production culture of these agencies established around sustainable supplies of provisioning services led to clashes with the growing sections of society calling for a greater emphasis on nature conservation (Buckman, 2008). One outcome has been the rapid expansion of the lands and seas dedicated as protected areas from the 1970s (State of the Environment Committee, 2011).

2.2. The changing role of governments in Australia

Australia is a federation. There is a Federal Government at the national scale, six state and two territory (provincial) governments, and over 500 local governments created by and responsible to the states. Under Australia's 1901 constitution, management of the environment and natural resources was left with the (previously independent) state governments, who now delegate aspects of local land use planning to local governments and regional natural resource agencies. However public dissatisfaction with the management of ecosystems by state governments has led to ongoing public pressure for Federal Government intervention using its constitutional power to regulate trading corporations and for domestic implementation of treaties. From 1999, the Federal Government

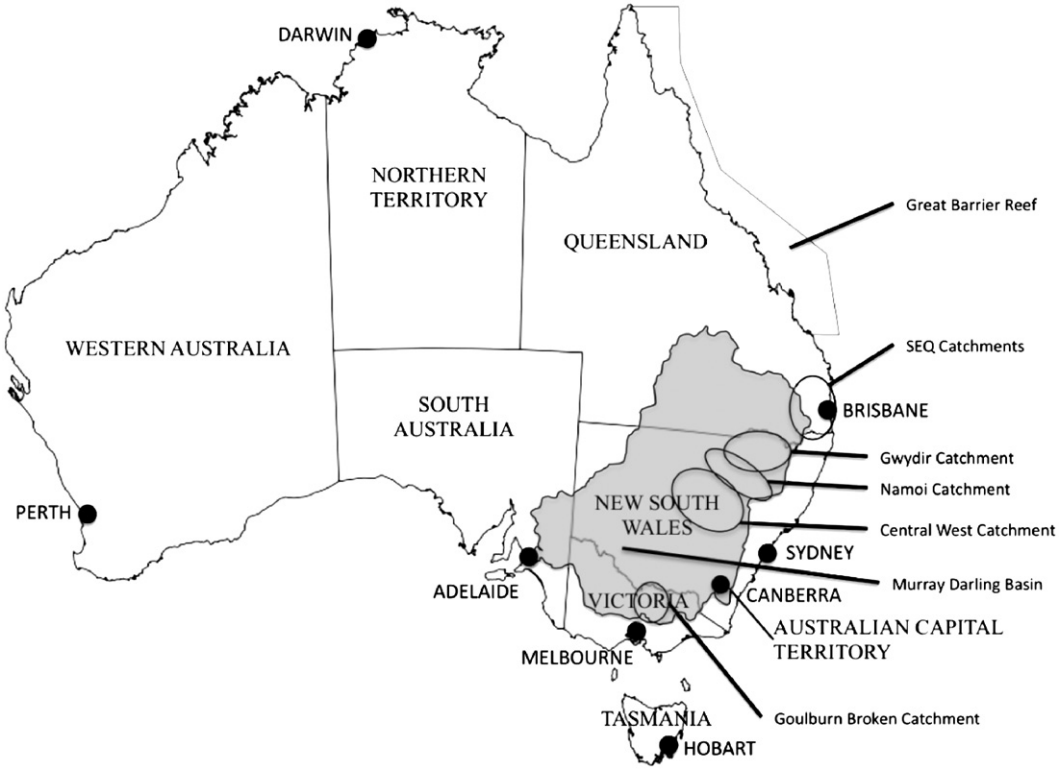

Fig. 1. Locations of major geographic areas and studies mentioned in the text.

used multilateral environmental agreements to define and regulate seven matters of national environmental significance (world heritage properties; national heritage places; wetlands of international importance; listed threatened species and ecological communities; migratory species protected under international agreements; Commonwealth marine areas; the Great Barrier Reef Marine Park; and nuclear actions, including uranium mines) (Australian Government, 1999). More recently, these two constitutional powers have been used to regulate aspects of water management and climate change, explicitly introducing the concept of ecosystem services into federal law (Australian Government, 2011a; Commonwealth of Australia, 2008).

Much of the dialogue about management of ecosystems for multiple benefits in Australia over the past several decades has been in the context of state versus federal responsibilities and authority. While institutions like the Council of Australian Governments, the National Water Commission (above), the Natural Heritage Trust (www.nht.gov.au/) (Crowley, 2001; Robins and Kanowski, 2011), the Murray Darling Basin Commission and the Murray Darling Basin Authority (www.mdba.gov.au/) (Connell, 2007, 2011) have developed cooperation among states and with the federal government. Yet the tensions between levels of government has often inhibited national strategic thinking on harmonising demands on the environment and the ability of ecosystems to meet those demands in the long term (Carron, 1985; Christoff, 1998; Cork, 2010a).

There has also been an ongoing conflict between governments' roles as promoters of development and as regulators in the public interest. This sparked the establishment of a new range of institutions from the 1970s dedicated to value different ecosystem service benefits, adjudicating on resource allocation and monitoring and reporting on the outcomes (a number of case are presented below in Section 3.2). Governments were proponents of more and more intensive agricultural development to populate the inland. As limits to natural resources were reached and with the rise of neo-liberal economics, governments began to change their roles to become regulators of competition for access to limited resources: a change of role from team captain to umpire that is contested today in regions such as the Murray-Darling Basin (Connell, 2007).

2.3. *Paradigms for recognising and managing multiple environmental values in Australia*

Several paradigms for natural resource management have been embraced in Australia although their application has often been wanting:

- Ecologically sustainable development has been a cornerstone of state and Australian government environmental policies since the early 1990s when the National Strategy for Ecologically Sustainable Development 1992 was adopted by all levels of government (Crowley, 2001; Dovers, 2001).
- The focus for planning and managing natural resources has increasingly become the catchment (watershed or river basin). In the 1980s and 1990s, Integrated Catchment Management (ICM) — the concept of integrating community involvement, technical knowledge, organisational structure and policy objectives at a catchment scale — guided thinking about how to manage resources at this regional scale (Bellamy et al., 2002).
- The concept of bioregions — regions with distinctive biological characteristics as indicated by soils, climate and biota — has become central to conservation planning. An Interim Biogeographic Regionalisation for Australia (IBRA) recognises 85 bioregions and 403 subregions (SEWPAC, 2012a).
- Increasingly, the skills and philosophies of Indigenous Australians are being recognised in natural resource management (SEWPAC, 2012b; Weir et al., 2011).
- Market-based approaches to protect biodiversity, increasing carbon sequestration, allocating and trading water, and managing

salinisation of land evolved and were improved throughout the 1990s and early 2000s (Eigenraam et al., 2005; Eigenraam et al., 2006; Mercer and Marden, 2006; Coggan et al., 2009).

Australia has become well-known since the 1990s for market-based measures for access to water and other natural resources. The establishment of these markets has also been a convenient way for governments to avoid some direct and controversial, administrative decisions on ecosystem services. However the creation of different and poorly-harmonised market-based incentives has created new externalities, for instance, promoting forest plantation establishment for timber and carbon sequestration at the cost of degrading freshwater-related ecosystem services (NWC, 2011; Pittock, 2011).

Other paradigms that have been employed to analyse and communicate relationships between Australians and ecosystems include ecological footprint (EPA, 2010), regional metabolism (Birkeland and Schooneveldt, 2003) and stocks and flows (Foran et al., 2005).

Potentially, the ecosystem services approach offers a framework around which all of these other concepts can be brought together. There is the opportunity to develop new governance arrangements based on readily communicable typologies of benefits and beneficiaries of ecosystem processes and the use of these typologies to define authority and responsibility for action across society (Australia21, 2007).

3. Acceptance and application of the concept of ecosystem services in Australia

3.1. Emergence of ecosystem services thinking in Australia

In Australia, the words "ecosystem services" have been used increasingly since the early 2000s. They now appear in most environmental policy documents and in some key environmental legislation. The concept has been embraced by some but treated with scepticism by others (van Kerkhoff et al., 2007). Those who have embraced ecosystem services have seen its potential to better frame and focus efforts to integrate environmental management. Others have seen it as a new way to advance old ideas and this has sometimes meant that the concept has been misinterpreted. For example, it has sometimes been argued that people provide ecosystem services, whereas mainstream ecosystem services thinking has increasingly differentiated the inputs of people from inputs from other species. Those who have been sceptical have often found it hard to see how an ecosystem services approach differs from previous approaches to sustainable environmental management. This is largely because Australia has a long history of efforts to recognise the contributions of "the environment" to its economy and society and new ideas can appear to be reinventions of these past approaches.

3.2. Some examples of how ecosystem services ideas have been applied

The following case studies, locations of which are shown in Fig. 1, illustrate the evolution of thinking and application of ecosystem services concepts in Australia.

3.2.1. Land use allocation

One of the earliest, most successful and long functioning Australian institutions for considering multiple values of land management is the Land Conservation Council, which is now known as the Victorian Environment Assessment Council. In 1969, when the Government of Victoria proposed to convert the semi-arid and biodiverse Little Desert to farms, there was extensive opposition from some government agencies and the public. Learning from the conflict, the Council was established with representatives from different government agencies plus non-government experts to transparently assess the values of each area of public land — using an approach similar to that which we would now call an ecosystem services evaluation — and make recommendations to the government on future land uses (Robin, 1988). One result is that Victoria now has one of the most representative protected area systems in the world (Frood and Calder, 1987).

Another attempt at strategic consideration of multiple social and ecological values was less successful. The Australian Government established a Resources Assessment Commission (RAC) in the Department of Prime Minister and Cabinet in 1989 and had it investigate controversial forest land-use and also proposed mining in the Kakadu region (a large protected area in the Northern Territory). The RAC was abolished in 1993 after only three investigations and without evaluation. Reasons proposed for the RAC's demise include: a change of Prime Minister, impatience with detailed enquiry, bureaucratic infighting, unreasonable expectations that clear answers could be provided, animosity by sectors who felt that their interests had been not served, concern at the political nature of subsequent decisions, and cost-cutting (Dovers, 2001). This case highlights the challenges of mainstreaming integrated decision making on ecosystem values in governments.

3.2.2. Regional natural resource management

Key publications in the late 1990s and early 2000s (Costanza et al., 1997; Daily, 1997) stimulated research on ecosystem services in Australia throughout the 2000s. Many of the projects in Australia have focused on only one or a few services. Several major collaborative studies have been undertaken at the catchment or regional scales, in which the concept of ecosystem services has been used as a framework for bringing scientists, farmers, industry leaders, and government policy makers together to consider dimensions of human dependence on ecosystems. Each of these projects encouraged participants to develop their own topologies of ecosystem services — based on their own knowledge and perceptions of value — and to develop strategic plans for better management of human–environment relationships (Abel et al., 2003; Binning et al., 2001; Bohensky et al., 2011; Bryan et al., 2010; Colloff et al., 2003; Cork et al., 2001, 2002; Karanja et al., 2007; Maynard et al., 2010; Olsson et al., 2008; Reid and Milligan, 2006). While limited to specific regions thus far, this approach has proven to be effective in building understanding of the issues, generating commitment to develop and implement actions, and creating policy within state government derived statutory land-use planning frameworks.

Building on these research projects, several catchment management bodies have used the concept of ecosystem services, in conjunction with ideas about social–ecological resilience and adaptability, to develop strategies aimed at managing social–ecological systems rather than the old approach of addressing individual symptoms of underlying problems (Bryan et al., 2010; Central West Catchment Management Authority, 2008, 2011; Goulburn Broken Catchment Management Authority, 2003; Maynard, et al., 2010; Namoi Catchment Management Authority, 2010; Olsson et al., 2008). These experiments have come at a time when there is considerable debate about reform to governance arrangements to achieve greater resilience and adaptability using the principles of subsidiarity (Cork, 2010b; Marshall, 2008, 2010; Marshall and Stafford-Smith, 2010).

3.2.3. Management of water

Another case is the National Water Initiative agreement between the state and federal governments in 2004 for the sustainable management of Australia's freshwaters and the establishment of the National Water Commission (NWC) as a champion of its implementation. This initiative has resulted in explicit recognition of a broad range of values provided by water-related ecosystem services. The biennial assessment reports undertaken by the NWC have highlighted deficiencies in implementation of policies for sustaining freshwater ecosystems compared to those associated with water market measures of benefit to irrigated agriculture (NWC, 2011).

3.2.4. Managing multiple values across borders: the Murray Darling Basin

Contested resources allocation has made the Murray-Darling Basin a focus for policy development. The Basin covers a seventh of Australia's land area, contains the nation's longest rivers and has generally low and highly variable flows. Extensive development of irrigated agriculture has resulted in greatly reduced availability of water for ecosystems, resulting in drying of wetlands, salinity, acidification, poisonous cyanobacteria blooms and loss of biodiversity (Pittock and Finlayson, 2011a). The Basin occupies parts of four Australian states and one territory. Since the 1990s there have been at least eight attempts to reform management of the Basin (Connell, 2007, 2011). In the latest approach the Federal Government has exerted direct control on water allocations under a 2007 law that requires the Murray-Darling Basin Authority (Authority) to set sustainable diversion limits to, in part, conserve capacity to generate ecosystem services. This is to occur through a Basin Plan, which seeks to reallocate water between consumptive uses and the environment (Pittock and Finlayson, 2011b). A recent study has shown that the potential benefits from ecosystem services are large but that there is a need for considerable effort to help affected stakeholders understand the nature of those benefits (CSIRO, 2012).

The development of the Murray-Darling Basin Plan provides many insights into the challenges of addressing multiple values across huge geographic areas and diverse stakeholders. There is an implicit assumption that if the trade-offs between competing values are identified then a rational process can be employed to resolve them: an assumption in ecosystem services approaches generally. Achieving this rational dialogue in the Basin has been difficult, however, because the debate has rapidly polarised into conservation versus production arguments and the many other economic and social benefits to people from healthy ecosystems have been overlooked (Pittock and Finlayson, 2011b). In common with other national policy agreements, the Australian federation lacks either adequate incentives for state governments to implement such an agreement or penalties for non-compliance (Pittock and Connell, 2010). Another insight relates to how the Authority has interpreted its responsibilities for protecting the ecosystem services associated with wetlands, which Australia is required to do under the Ramsar Convention (Pittock et al., 2010). The Authority has made the assumption that managing "ecosystem functions" will sustain generation of ecosystem services (Pittock and Finlayson, 2011b). The approach taken was to identify a set of critical hydrological ecosystem functions and to allocate water to sustain them. There was inadequate consideration of a broad range of ecosystem services, such as provisioning services from floodplain pastures and fisheries, cultural services associated with tourism, and regulating services like flushing salt out to sea (CSIRO, 2012; Reid-Piko et al., 2010). The lesson from this approach is that it would have been better to consider the full range of ecosystem services, benefits and beneficiaries in the initial planning stages as a way to guide prioritisation of water allocation. Some examples of this sort of approach in the Murray Darling Basin have emerged, which could be used as examples for further planning (Bryan et al., 2010; CSIRO, 2012)

3.2.5. Indigenous land and sea management

Australia's Indigenous people are often held up as an example of sustainable interaction between people and ecosystems. The progressive establishment, recognition and funding for Indigenous peoples' land and sea management agencies offers the prospect of realising both socio-economic and environmental conservation benefits. The return of land ownership titles over extensive areas has seen recognition that the socio-economic needs of Indigenous communities and the maintenance of the cultural and environmental values of their lands require new management institutions. The Australian Government has supported Indigenous communities to self-declare protected areas on their lands, which now total 50 declared protected areas covering 26 million hectares (a quarter of the area of reserves in the national system) (SEWPAC, 2012c). These declarations have highlighted the public, ecosystem services benefits from sound Indigenous land management, including conserving representative areas of biodiversity, controlling weeds and managing fire. In parallel, Indigenous communities pooled social security payments under the Community Development Employment Program and other revenues to establish Indigenous land and sea ranger programs (particularly in the Northern Territory, Queensland, South Australia and Western Australia). In 2007 the Federal Government began to directly fund these ranger programs in recognition of the social and ecosystem service benefits that they provide (Davies et al. 2011; SEWPAC, 2012b; Weir et al., 2011). These developments promise greater recognition of the rights and culture of Indigenous Australians, and also the injection of new thinking into broader Australian culture that is compatible with an ecosystem services approach (Luckert et al., 2007).

3.3. Contribution of Australian programs to theory and practice

3.3.1. Improving the use of ecosystem services as an interdisciplinary framework

When the concept of ecosystem services was first applied in Australia, in the late 1990s and early 2000s, attempts were made to bring economists, ecologists and environmental policy makers from Australia's three levels of government together to consider how the concept could be adapted as an interdisciplinary framework (Cork et al., 2002). This process revealed that not only do ecologists, economists and policy makers frame the issues around human dependence on ecosystems differently, but there are considerable differences in framing within these disciplines.

Some ecologists thought that simplifying the complexity of ecological processes to a small number of ecosystem services was artificial and potentially misleading, and some even questioned the usefulness of the concept of ecosystems themselves. Others welcomed ecosystem services as a way to communicate complex ecological ideas with a broad audience.

Some economists questioned what an ecosystem services approach offered beyond what environmental and ecological economics already offered (e.g., the concept of total economic value). Others saw some merit in the concept as a communication device but saw practical challenges. One of these challenges was the need to define ecosystem services in ways that would avoid double counting in benefit–cost analyses. Another was applying the concept of "marginal valuation" (i.e., assessing the economic implications of a change in supply of one service) when ecosystem processes and services interact with one another. A third

challenge was communicating with those who question the ethics of placing dollar values on many aspects of natural systems, particularly those of cultural significance.

Policy makers highlighted their need to consider what land management options to encourage, when it is likely that different services vary in different ways in relation to land conversion, making it probable that any policy setting will involve traded-offs between services, benefits and beneficiaries (Cork et al., 2007). Unfortunately, there has been relatively little effort made to consider the present and future needs of Australia's human population as a way to guide policies for managing ecosystem service outputs (Cork, 2010a).

In efforts to address these tensions, various projects in Australia separated ecosystem services from benefits and referenced ecosystem services and benefits to human needs, either from theory or by involving stakeholders in identifying their own needs (Binning et al., 2001; CSIRO, 2012; Maynard et al., 2010; Wallace, 2007). The clarification of benefits from ecosystems has been a trend internationally also (Fisher et al., 2008; Johnston and Russell, 2011), which has led to successful integration of ecology and economics in several major studies (TEEB, 2009; UK National Ecosystem Assessment, 2011).

Overall, the concept of ecosystem services has been a very useful focus for a decade of productive interdisciplinary dialogue in Australia, and the most recent projects have seen close alignment of the different needs and viewpoints of ecologists, economists and policy makers (CSIRO, 2012; Maynard et al., 2010).

3.3.2. Understanding the relationships between ecosystem processes and services

Interactions among ecologists and economists in Australia, as elsewhere, have identified the possibility of non-linear relationships between ecosystem change and ecosystem services delivery as a key challenge. Theory and empirical evidence suggests that different services are likely to follow different non-linear patterns of change as different components of biota respond to ecosystem change (Dobson et al., 2006). This requires that policies and land management decisions are adjustable depending on the current and projected state of land being managed (Cork et al., 2007). Constructing supply and demand curves that consider multiple non-linear responses among ecosystem processes and services is a major challenge for economists, especially when the ecological data are limited. One way in which this has been addressed in Australia is to rely on local expert judgment about which land uses might be most susceptible to changes in ecosystem services and which services are likely to be most sensitive to changes in land management (Binning et al., 2001). Recently, catchment management groups in parts of Australia have applied systems analysis and resilience theory to consider where critical thresholds might exist in relationships between ecological and social systems, which allow inferences to be drawn about demand and supply relationships in relation to ecosystem services (Central West Catchment Management Authority, 2008; Namoi Catchment Management Authority, 2010). Mapping of ecosystem functions in south–east Queensland has been used as a way to facilitate similar sorts of discussions in that region (Maynard et al., 2010). An important aspect of the Queensland work has been to consider the capacity of ecosystems to provide services, when the demand for the service is either not present or not recognised, versus actual supply when a demand exists.

3.3.3. Estimating social and economic values of ecosystem services

Most major studies of ecosystem services in Australia have been at landscape and catchment scales and have sought to consider changes in multiple ecosystem services in relation to several scenarios for future development. In some cases, analysis focused primarily on the biophysical and social implications of the scenarios, partly because there was insufficient data to perform robust economic analyses and partly because the decision makers involved felt that the biophysical and social analyses were the primary inputs they and their stakeholders needed (Abel et al., 2003; Maynard et al., 2010; Pert et al., 2010). In other cases, a range of economic valuation approaches was used to assess components of the scenarios, with care to avoid addition of value estimates where this could lead to double counting of benefits (CSIRO, 2012; Karanja, 2008; Karanja, et al., 2007).

At the interface between ecosystem services research and economic research in Australia, major advances have been made in the application of non-market valuation techniques (Bennett, 1999; Coggan et al., 2009; DEH, 2005; Gillespie et al., 2008; MacDonald et al., 2011; Whitten and Bennett, 2005).

The recent CSIRO study to assess the non-market values of the draft Plan for reallocating water in the Murray-Darling Basin (CSIRO, 2012) revealed a new challenge for ecosystem services valuation. Estimating non-market values requires assessment of the willingness of potential beneficiaries to pay for the benefits. This can be done using a variety of approaches, all of which involve documenting people's preferences in relation to clear choices. Modelling the biophysical processes in the Basin under baseline and Basin Plan conditions produces probabilistic estimates of the effects of the reallocation of water. It would be relatively straightforward to explore people's willingness to pay for certain improvements in benefits like food production, provision of clean water, protection from floods, recreational opportunities and protection of biodiversity. However, the question "what might people be willing to pay for the outcomes of the Basin Plan?" is really a question of what people would be willing to pay for the probability of certain benefits, when the uncertainty around some of those benefits is sometimes high. This illustrates a challenge that emerges when we move from valuations based on hypothetical outcomes to exploring the ecosystem services implications of plans that involve significant uncertainty.

An emerging trend in Australia is to combine thinking about ecosystem services, resilience and human wellbeing in government policy development and catchment-level management research (Nelson et al., 2010).

3.3.4. Connecting ecosystem services thinking to policy and management for sustainability

If it is accepted that an "ecosystem services approach" is one in which the full suite of benefits from the environmental are considered strategically, as we have argued earlier in this paper, then there have been only a few applications of a full ecosystem services approach in Australia to date (Abel et al., 2003; Maynard et al., 2010; Reid and Milligan, 2006). The words "ecosystem services", or similar terms, have appeared increasingly in policies and strategies at all levels of government over the past decade. The "ecosystem approach" has become the cornerstone of environmental policy in Australia (Australian Government, 2011b), as it has in several other countries. Ecosystem services frameworks are one approach being considered in the development of Australia's environmental-economic accounting and information systems (ABS, 2010; Australian Government, 2011c).

One example of the strategic use of an ecosystem services framework is in Victoria. In that state a few benefits from ecosystem services (maintenance of biodiversity habitat, carbon sequestration and hydrological regulation) have been targeted as being most critical and amenable to intervention. Reverse auctions have been used both to allocate funds to protect and

enhance the ecosystem services efficiently and to obtain information on the state of these services through the processes of receiving bids for government investment (Eigenraam et al., 2005, 2006).

A second example is the development of an 'agreed' ecosystem services framework developed by stakeholders in south–east Queensland. The framework assesses 28 ecosystem services derived from the regions ecosystems and the contributions these services make to the well-being of the community. Ecosystem services has since become a policy embedded in the statutory regional planning document mandated by the state government, as well as State of Region reports and other natural resource management documents and local government planning schemes. Use of the framework is the identified Programme to meet this policy and programs are currently being developed to support landholders supplying ecosystem services (Maynard et al., 2010). In various other projects around Australia, the idea of ecosystem services has been used as a focus for dialogue within rural and peri-urban communities about how to balance rural land management with conservation objectives (e.g., Ampt et al., 2010).

In north Queensland, increased pressure on the Great Barrier Reef from terrestrial runoff, over-harvesting, and climatic changes triggered a major reform in policy and management in the region. Under the guidance of the Great Barrier Reef Marine Authority, the focus of governance has shifted from protection of selected individual reefs to stewardship of the larger-scale seascape. A recent analysis of this transition concluded that its success has been largely due to the high quality interplay between multiple individual actors, organisations, and institutions at multiple levels. The concept of ecosystem services was a key enabler of this interplay (Olsson et al., 2008). This example also illustrates how thinking about governance for achieving resilience of coupled social–ecological systems has advanced in Australia even though understanding of the ecological processes underpinning delivery of ecosystem services is improving but remains relatively poor (Bohensky et al., 2011; Stoeckl et al., 2011).

In most of the instances where elements of an ecosystem services approach is said to be applied, however, no clear goals have been set for managing ecosystem services and there is little attention to what the needs of Australia's human population are now and might be in the future. It has been argued that there is a need for a better national strategic approach to manage the interactions between people and the environment, and that language and concepts brought together in an ecosystem services framework would be a good way to facilitate the required strategic dialogue (Australia21, 2007; Australian Government, 2011b; Cork, 2010a; Cork et al., 2007).

4. Discussion: key lessons and remaining challenges

4.1. Taking advantage of opportunities provided by an ecosystem services approach

In some instances Australia has embraced the opportunities offered by the concept of ecosystem services. Ecosystem services concepts and frameworks have been at the heart of several large-scale collaborations between scientists, communities and policy makers that have considered past, present and future dependence of humans on ecosystems, usually at a regional scale. Furthermore, ecosystem services language has been used extensively as a communication tool by governments and non-government organisations to explain the dependence of humans on ecosystems.

In other ways, however, opportunities have been overlooked. Despite major progress in many aspects of environmental management, Australia lacks effective frameworks and governance arrangements to consider human–environment interactions holistically and strategically at a national level, and such thinking at a regional level has occurred in very few places. Ecosystem services are referred to in many public documents as being important but without much explanation about what they mean and how a society might address its relationship with ecosystems. Strategic environmental decision making has been an objective of many in Australia's bureaucracies for many years, but achieving it has been hampered by poor leadership, restructuring of departments and marginalisation of environmental agencies (Ross and Dovers, 2008). Some groups in Australia have argued that the importance of ecosystem services across society is so great that the only effective way to manage them is by including individuals and organisations from across society in a national strategy (Australia21, 2007).

There has been a tendency for ecosystem services to be equated with market-based approaches to natural resource management. As a result, the potential to use the concept of ecosystem services to enhance dialogue about broader social implications of human dependence on ecosystems has been overlooked in much public debate. In addition, concerns are sometimes voiced about the impact on voluntary land stewardship of paying people for ecosystem service provision (S. Maynard, personal communication, March 2012).

4.2. New challenges revealed by large-scale management programs

In the Murray-Darling Basin case study we described how the ambitious attempts to manage multiple values among multiple stakeholders across six jurisdictions have allowed Australia to try new approaches and to learn lessons. Two key lessons have been: (1) it is important to start by considering the relationships between ecosystem processes, services benefits and beneficiaries as a way to inform planning; and (2) assessing people's preferences for different land and water management options becomes much more complex when they can only be offered probabilities of benefits rather than clear expectations, even though probabilities is all that can realistically be offered in most cases. It is not realistic to expect the relationships between ecosystem processes, services benefits and beneficiaries to be ever fully understood (and, anyway, the relationships will not be constant), but considering the nature of these relationships is a way to focus the planning process on what information is needed if we hope to balance human dependence on ecosystems with the meeting of human needs. Two measures may contribute to a better outcome in the Murray-Darling Basin, perhaps in the next iteration of planning. One would be to build on CSIRO's work (CSIRO, 2012) to develop a clearer understanding on the part of the Basin Authority of ecosystem services and the use of the concept to draw on the knowledge and values of stakeholders, identify and document relevant services and incorporate these understandings into planning. The other would be to draw on the experience of the Victorian Environment Assessment Council and catchment management agencies (as discussed above) to consider ecosystems, values and services through strategic regional dialogue in a staged approach that seeks to build understanding and agreement among stakeholders for future management.

4.3. Polarisation of debates into conservation for biodiversity vs. provisioning services

At the international level there has been a debate about whether maintenance of biodiversity is a service or an underpinning ecosystem process (Millennium Ecosystem Assessment (MA), 2003). It could be argued that maintenance of genetic and species diversity, which are key components of ecosystems and

underpin ecological processes, is itself an ecological process that supports other processes. In this sense, maintenance of species could be seen as an "intermediate ecosystem service" (Fisher et al., 2008). On the other hand, biodiversity is a human-generated concept and conservation of a diversity of species is a benefit to those humans who value the knowledge that species are being protected. These might seem to be esoteric arguments, but they become real when the ideologies of people and organisations that see conservation as a moral issue clash with those who think conservation is one of the values that humans obtain from ecosystems. Our experience in Australia is that the concept of ecosystem services has not yet managed to encompass both of these viewpoints and that limits its acceptance and usefulness.

In Australia, conservation of biodiversity has traditionally been the policy focus for environment departments at both the national and state levels. Management of agricultural landscapes and production forests has been the focus for agriculture and forestry departments. In some states these foci have been combined within single departments. When the concept of ecosystem services was first introduced considerable interest was shown by forestry and agricultural industries and policy makers. Some saw this approach as a way to explore trade-offs and reach consensus between conservation and production interests. Others saw it as a way to promote these industries in a more positive light, by highlighting the ecosystem services that might be enhanced by good stewardship. However some conservation agencies and interest groups feared that conservation for its intrinsic worth would be overlooked in favour of the direct and indirect use values of biodiversity. Others were opposed to the idea of considering native species as being "in the service of people". We suggest that this tension between production and conservation sectors is one factor that has worked against a national strategic approach to managing human–environment interactions in Australia.

4.4. Mechanisms for better governance

Australian society is still struggling with how to integrate things that have intrinsic value with things that have use-value to humans, and how to avoid basing decision making on one approach or the other. When trying to plan environmental management over very large spatial scales there are challenges in engaging stakeholders adequately so that they understand their relationship with the environment and can make sensible decisions as a result. This communication challenge applies whatever approach to large-scale environmental management is used. In the past communication has been used to tell stakeholders what the government intends to do. The use of an ecosystem services framework holds the possibility of collaborative decision-making and devolved governance so that environmental management is more effective and efficient. This is perhaps the biggest challenge facing environmental policy makers in Australia, but it is one that also offers many opportunities.

Managing ecosystems across a continent as large as Australia is a major challenge. Rural communities were supported by governments from the 1980s to form landcare groups: voluntary organisations for environmental and natural resources management. A moderate portion of farmers participated (Curtis and Lockwood, 2000). However they were criticised as being unstrategic. From the 1990s, landcare was supported by multi-stakeholder, regional natural resource management bodies (often called catchment management authorities) formed under state laws. These were formed to devolve the responsibility and opportunity to identify regional priorities for management of natural resources and advise on resource allocation. Some regional bodies are government entities and others operate as non-government organisations. The advisory versus management roles of these bodies has varied between states and over time. Rivalry with state government environment and natural resource departments has frequently seen these bodies enhanced, changed frequently and diminished.

Australian and international experience suggests that institutions for environmental governance are most effective when there is institutional continuity and an independent source for at least part of the required income (Pittock, 2009; Ross and Dovers, 2008). For example and in contrast with Australia, Brazilian law enables river basin consortia to levy rates on catchment residents to fund part of the cost of ecological restoration (Pereira et al., 2009). To be effective these regional organisations need a clear understanding of the roles of local institutions in agreeing on locally appropriate means of instituting policies of state and national governments, to prioritise interventions and assess their effectiveness (Pannell and Roberts, 2010; Pannell et al., 2012; Robins and Dovers, 2007).

5. Conclusions

Australia has been a pioneer in piloting new systems in attempts to identify and better value and manage ecosystem services. There are early examples of best practice, such as conserving catchments for water supplies. Several studies have shown how a wide range of stakeholders can be engaged in strategic dialogue about managing regional natural resources using an ecosystem services framework, including developing ecosystem services frameworks that have been accepted into regional land-use policy. There are also exciting larger-scale developments like the growing strength of Indigenous land and sea management institutions.

There has been much less success in using ecosystem services frameworks to facilitate strategic dialogue within and among governments at state and national scales. This lack of national strategic thinking has contributed to a systemic failure to implement important policy commitments well, contributing to an ongoing decline in the health of Australia's ecosystems. Environmental markets have been established for key individual resources but not multiple (bundled) ecosystem services, and poor design has created new externalities between such mechanisms as water and forests. Voluntary and regional natural resource management institutions have been fostered then disempowered with constant changes in mandates, form and funding. Important intergovernmental agreements to conserve biodiversity, water and other environmental attributes have been conceived but lacked the incentives for full state government implementation and penalties for non-compliance.

Better performance requires institutional reforms: stable and more consistently resourced regional management institutions and more integrated governance stemming from leadership, integration mandates, vertical and horizontal integration mechanisms and accountability institutions.

At its heart the decline in Australia's ecosystems can be attributed to a habit of seeing every ecological debate as a contest between biodiversity and socio-economic benefit, where the resulting compromise decisions diminish ecosystem health. The ecosystem services concept provides an increasingly rigorous framework to engage a broad range of stakeholders in considering these debates in a more sophisticated light. Using this framework to identify a greater diversity of ecosystem services and options for their management can help Australian institutions choose actions to provide a broader range of benefits for people.

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